AFQTP 3E0X1-13
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# AIR FORCE

# QUALIFICATION TRAINING PACKAGE (AFQTP)

for

ELECTRICAL SYSTEMS

(3E0X1)

## MODULE 13

## ELECTRICAL FUNDAMENTALS

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## MODULE 13
## ELECTRICAL FUNDAMENTALS



Career Field Education and Training Plan (CFETP) references from 1 Apr 97 version.

OPR: HQ AFCESA/CEOF
(SMSgt Mike Trevino)

Certified by: HQ AFCESA/CEO
(Colonel Lance C. Brendel)

**Notice.** This AFQTP is *NOT* intended to replace the applicable technical references nor is it intended to replace hands-on training. It is to be used in conjunction with these for training purposes only.

# AIR FORCE QUALIFICATION TRAINING PACKAGES
**for**
**ELECTRICAL SYSTEMS**
**(3E0X1)**

## INTRODUCTION

***Before starting this AFQTP,*** refer to and read the "Trainee/Trainer Guide" located on the AFCESA Web site **http://www.afcesa.af.mil/.** This guide will be found at each AFS's AFQTP download page.

***AFQTPs are mandatory and must be completed*** to fulfill task knowledge requirements on core and diamond tasks for upgrade training. ***It is important for the trainer and trainee to understand*** that an AFQTP ***does not*** replace hands-on training, nor will completion of an AFQTP meet the requirement for core task certification. AFQTPs will be used in conjunction with applicable technical references and hands-on training.

***AFQTPs and Certification and Testing (CerTest) must be used as minimum upgrade requirements for Diamond tasks***.

## MANDATORY minimum upgrade requirements:

***Core task:***
AFQTP completion
Hands-on certification

***Diamond task:***
AFQTP completion
CerTest completion (80% minimum to pass)

***Note:*** *Trainees will receive hands-on certification training when equipment becomes available either at home station or at a TDY location.*

***Put this package to use.*** Subject matter experts under the direction and guidance of HQ AFCESA/CEOF revised this AFQTP. If you have any recommendations for improving this document, please contact the Electrical Career Field Manager at the address below.

HQ AFCESA/CEOF
139 Barnes Dr. Suite 1
Tyndall AFB, FL 32403-5319
DSN: 523-6392, Comm: (850) 283-6392
Fax: DSN 523-6488
E-mail: ceof.helpdesk@tyndall.af.mil

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# ELECTRICAL FUNDAMENTALS

## MODULE 13 AFQTP UNIT 1

## IDENTIFY ELECTRICAL TERMS AND SYMBOLS (13.1.)

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# IDENTIFY ELECTRICAL TERMS AND SYMBOLS

## *Task Training Guide*

| | |
|---|---|
| **STS Reference Number/Title:** | 13.1. – Electrical fundamentals, identify electrical terms and symbols. |
| **Training References:** | • CDC 3E051A, Vol. 2 |
| **Prerequisites:** | • Possess as a minimum a 3E031 AFSC. |
| **Equipment/Tools Required:** | • None |
| **Learning Objective:** | • Correctly identify electrical terms and symbols given |
| **Samples of Behavior:** | • Recognize and identify electrical terms and symbols. |

# IDENTIFY ELECTRICAL TERMS AND SYMBOLS

**Background:** You will discover that there are many electrical terms and symbols that you need to know to properly do your job. In this unit we will be discussing some of the more common terms and going over some common symbols you may see and use.

***To perform this task, follow these steps:***

**Step 1: Identify current flow.**

- The uniform movement of free electrons in a specific direction is current flow.
- We measure current flow by counting the number of electrons that pass a given point in 1 second.

> **NOTE:**
> The charge of each electron is too small and they are too numerous to count physically. Coulomb, a French scientist, developed a method of counting the electrical charges. He determined it would take $6.28X10^{18}$ of these charges to make up a unit.

- This unit is called a Coulomb. This is just a quantity of electrons that is measured in a way similar to the way you measure gallons of water.

> **NOTE:**
> To indicate how much water is flowing in a pipe, we say so many gallons per minute. If one Coulomb unit of charge passes through a given point in a conductor in 1 second, we refer to it as 1 ampere (amp) of current flowing in the line or conductor.

- Thus, the unit of measure for current flow is the ampere.
- The symbol for current is “I” (representing intensity of current), which we use in math formulas.
- The for the unit of measure is “a” or “A” (for quantity of amperes) **Step 2: Identify voltage.**
- Voltage is one of the most important concepts of electronics. Our entire study of electronics hinges on this and several other concepts.
- In order to move electrons to perform a useful job, there must be a force capable of causing the electrons to move.
- This force that moves the electrons is voltage.

> **NOTE:**
> We also refer to voltage as electrical pressure, difference of potential, or electromotive force(EMF).

- The basic unit of measure is the volt.
- The symbol for voltage is “E.”
- The symbol for the unit of measure is "V" or "v".

**Step 3: Identify resistance.**

- Up to now, we have discussed the movement of electrons (current) and the force that causes those electrons to move (voltage). Now, it is time to look at the opposition those electrons encounter as they move through the conductors.

> **NOTE:**
> Most materials are in a state of atomic balance. Because of this, these materials are reluctant to give up their electrons. For this reason, some pressure (voltage) is required to move the electrons in even the best conductors.

- This opposition to current flow that is offered by a material is called resistance.
- All forms of opposition to current flow are measured or calculated in ohms.
- This unit of measurement states that when 1 volt of pressure pushes 1 ampere of current flow through an electrical path, then 1 ohm of resistance is present. This relationship between the three factors of electricity is referred to as Ohm's law.
- The symbol we use in math formulas to figure resistance is "R".
- The symbol we use on electrical drawings is the omega ($\Omega$).

**Step 4: Identify inductive reactance.**

- Inductance is indicated with the letter L.
- Its unit of measurement is the henry.
- In an AC circuit containing inductance, inductance opposes a change of current in a circuit.
- The extent of this opposition depends on two things, the <u>frequency</u> of the applied voltage and the <u>amount of inductance</u> that is present in the circuit.
- This opposition is known as inductive reactance.
- Common inductive loads are anything with windings such as coils, motors and transformers.
- Inductive reactance is identified by the symbol $X_L$
- We measure it in ohms.

**Step 5: Identify capacitance.**

- Capacitance in a circuit in a circuit opposes any change in voltage.The unit of capacitance is called the farad.
- The symbol for capacitance is C.
- A capacitor is a device that introduces a capacitance into a circuit.
- A capacitor stores a charge until a change in voltage occurs then it discharges in an attempt to maintain a constant voltage.

> **NOTE:**
> When you place a capacitor in an AC circuit, it stores electricity on one alternation; when the current is at the point of reversing polarity on the other alternation, the capacitor discharges in the original current direction to continue the flow until it discharges. It then recharges and repeats its action in the other direction on the second alternation.

- This opposition is called capacitive reactance and is measured in ohms, just like inductance, but we designate it with the symbol $X_C$.

**Step 6: Identify impedance.**

- Impedance is the term we use to signify the total opposition to the flow of AC in a circuit.
- It is the combined effect of the total reactance and the resistance.
- The total reactance is the difference between $X_L$ and $X_C$.
- The symbol for impedance is Z.
- It has the same unit of measurement as resistance, the ohm, because it opposes current flow.

**Step 7: Identify power.**

- The most widely used definition of the term power is "the rate of doing work." This is for any form of power, mechanical or electrical.
- In an electrical circuit, power is the product of voltage and current.
- The unit of measurement for electrical power is the watt or kilowatt. A kilowatt is 1,000 watts; we often use this term because a watt is such a small unit.
- The symbol we use in a drawing to show the amount of power is "W."
- The symbol we use in a math formula to denote power is "P."
- The following terms are used daily in our career field and are associated with power:
- Force: That which produces, or tends to produce, a change in motion of a body. In electronics, electrical force causes electrons to move from one point to another.
- The unit of force is the dyne.
- Work: Is the production of motion against a resisting force. In electronics, electromotive force causes electrons to move against the opposing force offered by the resistance in a circuit.
- When an ampere of current flows through a resistance of 1 ohm for 1 second, it does a joule of work.
- Energy: Is the capacity or ability to do work. Energy that is due to motion of matter is called kinetic energy, whereas energy that is due to the position of matter is called potential energy. Energy may be transformed into such forms as heat, light, and motion. It may be transformed from one form to the other, as is done in producing electron flow by mechanical or chemical means.
- Since energy is the capacity to do work, energy and work have the same unit (joule).

**Step 8: Identify frequency.**

- When an AC generator completes a positive and a negative altenation, you say it completes one electrical cycle.
- The cycle is represented with the symbol ~.
- The number of times each cycle occurs in 1 second is called frequency.

> **NOTE:**
> The frequency is expressed in cycles per second or simply hertz.

- The symbol used in math for frequency is "f."

# Review Questions
**for**
# Identify Electrical Terms and Symbols

| Question | Answer |
|---|---|
| 1. What is the unit of measure for current flow? | a. Ohm<br>b. Joule<br>c. Ampere<br>d. Henry |
| 2. The unit of measure for  amperes used on drawings is “I.” | a. True<br>b. False |
| 3. What is the definition of voltage? | a. The uniform movement of free electrons<br>b. The force that moves electrons in an electrical circuit.<br>c. Opposition to current flow.<br>d. The production of motion against a resisting force. |
| 4. The unit of measurement for inductance is the farad. | a. True<br>b. False |
| 5. Power is the product of voltage and _____. | a. Resistance.<br>b. Inductance.<br>c. Current.<br>d. All of the above. |
| 6. The frequency is expressed in cycles per minute or simply hertz. | a. |

## IDENTIFY ELECTRICAL TERMS AND SYMBOLS

| Performance Checklist | | |
|---|---|---|
| **Step** | **Yes** | **No** |
| 1. Did the trainee properly identify the electrical terms? | | |
| 2. Did the trainee properly identify the electrical symbols? | | |

**FEEDBACK:** Trainer should provide both positive and/or negative feedback to the trainee immediately after the task is performed. This will ensure the issue is still fresh in the mind of both the trainee and trainer.

# ELECTRICAL FUNDAMENTALS

## MODULE 13 AFQTP UNIT 3

## CONSTRUCT BASIC ELECTRIC CIRCUITS (13.3.)

# CONSTRUCT BASIC ELECTRIC CIRCUITS

## *Task Training Guide*

| | |
|---|---|
| **STS Reference Number/Title:** | 13.3. – Electrical fundamentals, construct basic electrical circuits |
| **Training References:** | • CDC 3E051 Set A Vol. 2 |
| **Prerequisites:** | • Possess as a minimum a 3E031 AFSC. |
| **Equipment/Tools Required:** | • Power source<br>• Wire<br>• Light or load<br>• General tool kit |
| **Learning Objective:** | • Given scenario, construct basic electrical circuits |
| **Samples of Behavior:** | • Construct basic electrical circuits using approved equipment and method |
| **Notes:** | |
| • Any safety violation is an automatic failure. | |

**Notice.** This AFQTP is *NOT* intended to replace the applicable technical references nor is it intended to replace hands-on training. It is to be used in conjunction with these for training purposes only.

# CONSTRUCT BASIC ELECTRIC CIRCUITS

**Background:** A simple circuit is made up of a voltage source, the necessary connecting wires, and some type of load. An electric circuit is a completed conducting pathway. As an example, a lamp connected by conductors across a dry cell battery forms a simple electric circuit. Figure 1 below shows a simple circuit with one power source (E1) and three resistive loads (R1, R2, & R3). This drawing is a series circuit, a simple circuit has only one load.

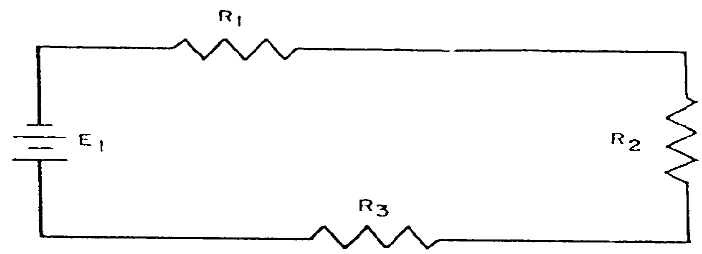



**Figure 1, Series circuit**

A parallel circuit is defined as one having more than one current path connected to a common voltage source. Parallel circuits, therefore, must contain two or more load resistance's which are not connected in series.

Series and parallel circuits can be considered separately. However, the technician will seldom encounter a circuit that consists solely of either type of circuit. Most circuits consist of both series and parallel elements. A circuit of this type will be referred to as a SERIES-PARALLEL circuit.

***To perform the tasks, follow these steps:***

**Step 1: Construction of a Series Circuit.**

- Current flows from the negative (-) terminal of the battery through the lamp to the positive (+) battery terminal.
- As long as this pathway is unbroken, it is a closed circuit and current will flow. However, if the path is broken at any point, it is an open circuit and no current flows. (Figure 2)

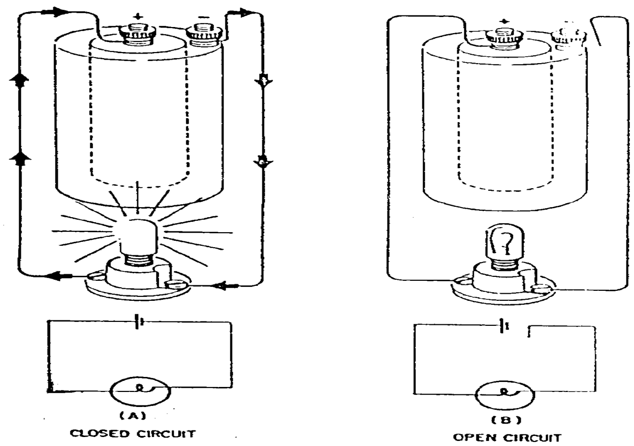



**Figure 2, Basic Series Circuit**

- There is only one path for current flow in a series circuit.

- When you construct a series circuit you should follow a wiring diagram or schematic drawing of some kind. It could be one provided by an electrical engineer, a manufacturer, or one you have drawn out.

**SAFETY:**
**ENSURE POWER IS OFF BEFORE CONSTRUCTING ANY CIRCUIT**

**NOTE:**
The important point to remember is to start at one point and systematically follow the drawing until you have all components drawn on the circuit built into your circuit.

**Step 2: Construction of Parallel Circuits.**

- Constructing a parallel circuit is very similar to constructing a series circuit.
- You need to have a power source, conductors, and at least two loads.
- The difference is that the resistors are connected in parallel or side by side instead of hooking them up end to end like you did for the series circuit.
- An example of a basic parallel circuit is shown in Figure 3.

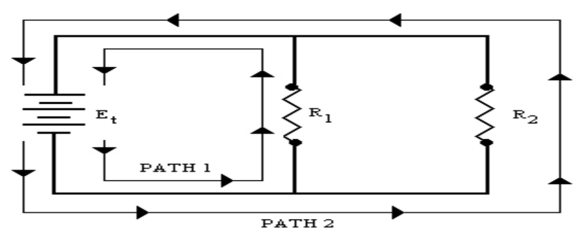
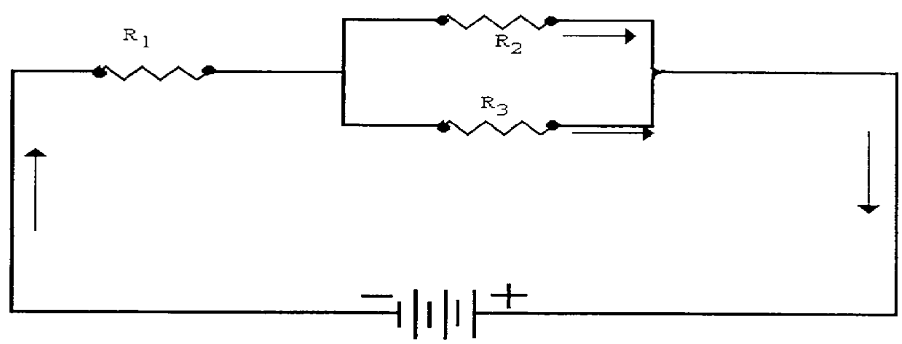



**Figure 3, Basic Parallel Circuit**

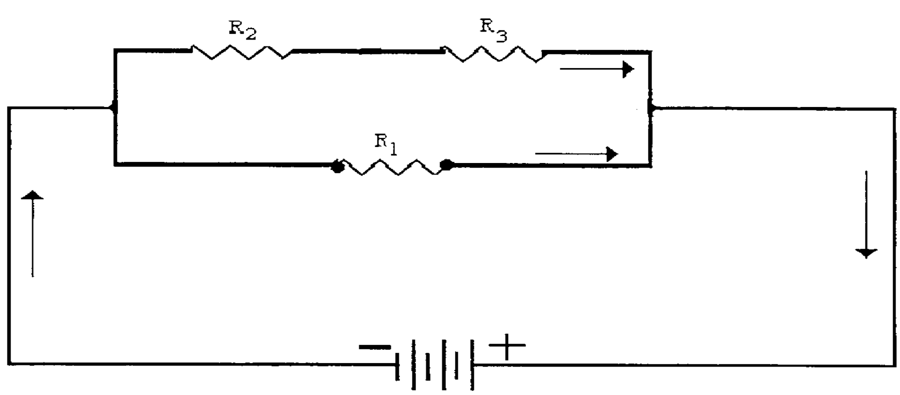
- Starting at the voltage source ($E_t$) and tracing counterclockwise around the circuit, two complete paths can be identified in which current can flow.
- One path is traced from the source through resistance $R_1$ and back to the source: the other, from the source through resistance $R_2$ and back to the source.

**Step 3. Construction of Series-Parallel Circuits.**

- At least three units of resistance are required to form a series-parallel (complex) circuit.
- Two basic series-parallel circuits are shown in Figure 4.
- In Figure 4(A), $R_1$ is connected in series with the parallel combination made up of $R_2$ and $R_3$, and in (B) $R_1$ is in parallel with the series combination of $R_2$ and $R_3$.




**A,** $R_1$ IN SERIES WITH PARALLEL COMBINATION OF $R_2$ AND $R_3$




**B,** $R_1$ IN PARALLEL WITH SERIES-PARALLEL COMBINATION OF $R_2$ AND $R_3$

**Figure 4, Series-Parallel Circuit**

# Review Questions
**for**
# Construct Basic Electric Circuits

| Question | Answer |
|---|---|
| 1. A simple circuit is made up of a ________. | a. Voltage source.<br>b. Necessary connecting wires.<br>c. Some type of load.<br>d. All of the above. |
| 2. An electric circuit is a completed conducting pathway. | a. True<br>b. False |
| 3. What simple circuit is defined as one having more than one current path connected to a common voltage source? | a. Series<br>b. Parallel<br>c. Series-parallel<br>d. Schematic |
| 4. How many units of resistance are required to form a series-parallel (complex) circuit? | a. Two<br>b. Three<br>c. Four<br>d. None of the above |

# CONSTRUCT BASIC ELECTRIC CIRCUITS

| Performance Checklist | | |
|---|---|---|
| **Step** | **Yes** | **No** |
| 1. Did trainee ensure all power sources were disconnected before constructing electrical circuits? | | |
| 2. Did trainee construct a series circuit? | | |
| 3. Did trainee construct a parallel circuit? | | |
| 4. Did trainee construct a series-parallel circuit? | | |

**FEEDBACK:** Trainer should provide both positive and/or negative feedback to the trainee immediately after the task is performed. This will ensure the issue is still fresh in the mind of both the trainee and trainer.

# ELCETRICAL FUNDAMENTALS

## MODULE 13 AFQTP UNIT 4

## COMPUTE FOR VOLTAGE, CURRENT, RESISTANCE, AND POWER (13.4.)

# COMPUTE FOR VOLTAGE, CURRENT, RESISTANCE, AND POWER

## *Task Training Guide*

| | |
|---|---|
| **STS Reference Number/Title:** | 13.4. – Electrical fundamentals, compute for voltage, current, resistance, and power |
| **Training References:** | • CDC 3E051A, Vol. 2 |
| **Prerequisites:** | • Possess as a minimum a 3E031 AFSC. |
| **Equipment/Tools Required:** | • None |
| **Learning Objective:** | • Given scenario, compute for voltage, current, resistance, and power |
| **Samples of Behavior:** | • Follow the required steps to compute for voltage, current, resistance, and power. |

## COMPUTE FOR VOLTAGE, CURRENT, RESISTANCE, AND POWER

**Background:** In order for current to flow, two things are essential: there must be a source of electrical power (voltage) and there must be a complete circuit. The source of voltage can be a battery, a generator, or some other device. The complete circuit means that there must be a complete path from the source through the load and a return back to the source. In this unit we discuss the relationship of voltage, current, and resistance, and the application of Ohm's law.

**Ohm's law application.**

- There is a definite relationship among the voltage, current, and resistance of any circuit or part of a circuit. If the voltage is increased, the current increases proportionately;,if resistance stays the same. if the resistance is increased, the current decreases proportionately if voltage stays the same.

> **NOTE:**
> A German scientist, put first name Ohm, developed a law for the quantities of a circuit as follows: 1 volt is the pressure required to force 1 ampere of current through a resistance of

- Ohm's law, simply stated, is as follows: "For any circuit or part of a circuit, the current in amperes is equal to the electromotive force in volts divided by the resistance in ohms."
- This means that, if you know the voltage and resistance, you can determine the current by dividing the voltage value by the resistance.
- This relationship is expressed by the following equation: *Current = Voltage/Resistance*
- You can also find the values of voltage and resistance if you know any two of the other values. The following equations show this: *Resistance = Voltage / Current; Voltage = Current x Resistance*
- Using the symbols for current (I), voltage (E), and resistance (R), you can state ohms law as follows: E = I x R; I = E / R; R = E / I.
- Look at Figure 1, to see Ohm's law in a circular representation.

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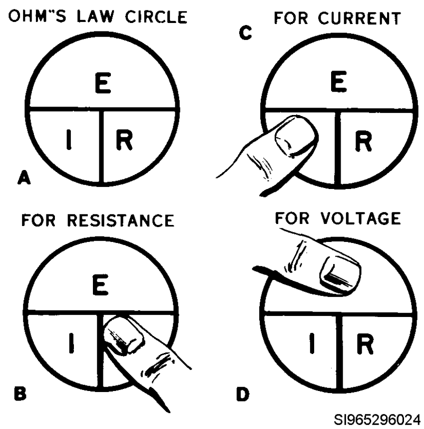


**Figure 1, Ohm's Law Circle**

- To use the circle, simply cover the value you wish to determine.
- Use the remaining values in the formula to determine the unknown.
- Here's an example: A circuit has an applied voltage of 120 volts and a resistance of 20 ohms.
- To find the current flow, simply apply Ohm's law as follows: I = E / R
- Next enter the known values: I = 120 / 20 = 6 amps.

**Application of Ohm's law to direct current –series circuits.**

- A series circuit is defined as "a circuit that has only one path of current flow."
- Figure 2 shows the arrangement of a series circuit.

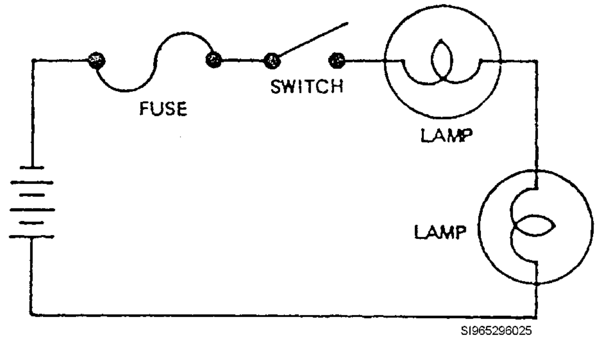


**Figure 2, Arrangement of Units in a Series Circuit**

- Each electrical circuit has certain operating characteristics. The three characteristics of a series circuit are as follows: **1**. Total resistance is the sum of the individual resistors ($R_T = R_1 + R_2 + R_3$ + etc.), **2.** Same current flows in each part of the circuit ($I_T = I_1 = I_2$ = etc.), and **3.** Applied voltage divides among the resistors according to their resistance ($E_T = E_1 + E_2$ + etc. and $E_1 = IR_1$; $E_2 = IR_2$.) The sum of the voltage drops in each resistor equals the applied voltage.(Et=E1+E2+E3+etc.)

- Knowing these characteristics along with Ohm's law, you will be able to compute for voltage, current, and resistance.
- Using Figure 3 as an example; it has a 120-volt source of power, a fuse, a switch, and two 30-ohm resistors in series.

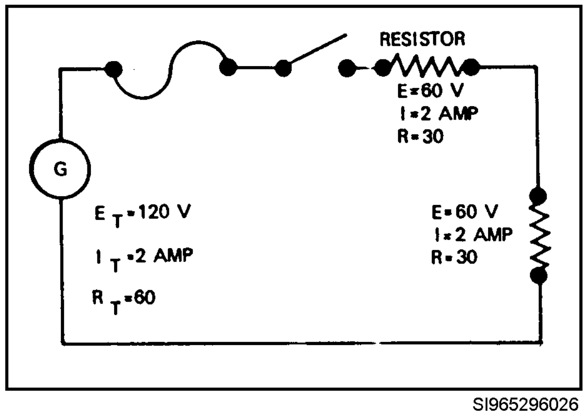


**Figure 3, Series circuit with equal resistors**

- Since the total resistance of a series circuit is equal to the sum of the resistors, then the total resistance for this circuit is 30 ohms plus 30 ohms, or a total of 60 ohms. ($R_T$ = 60)
- You were already given the total voltage (120 volts). Knowing the total voltage and the total resistance, you can now find the total current flow by using Ohm's law.
- I = E / R = 120 / 60 = 2 amperes
- Since the same current flows in each part of a series circuit, a current of 2 amps flows through each of the two resistors.
- Use Ohm's law again to see how the voltage divides among the resistors.
- $E_1 = I \times R_1 = 2 \times 30 = 60$ volts

**NOTE:**
This is the same for each resistor since the resistance is the same in both. resittors

- Figure 4 shows how voltage divides among unequal resistors in a series circuit. Note that the unit with the most resistance uses most of the voltage.

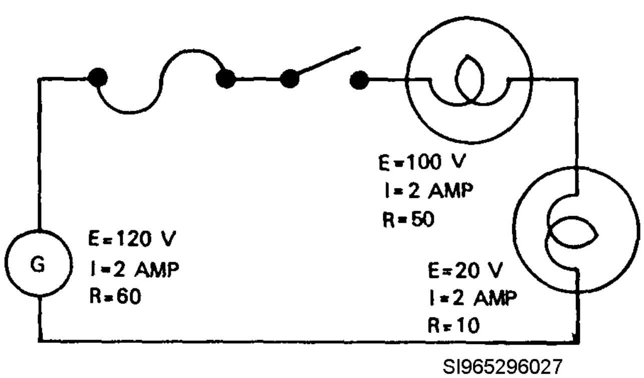


**Figure 4, Series Circuit with Unequal Resistors**

**Application of Ohm's law to direct current-parallel circuits.**

- Parallel circuits are circuits in which the components are arranged in such a manner that the current divides between them.
- Unlike a series circuit, a parallel circuit has two or more paths for current to flow.
- The characteristics of a parallel circuit are **1.** The same voltage is applied across each branch, ($E_T = E_1 = E_2 =$ etc.), **2.** The total current in a parallel circuit is equal to the sum of the current flow in the individual branches. ($I_T = I_1 + I_2 + I_3 +$ etc.), and **3.** The total resistance of a parallel circuit is equal to the applied voltage divided by the total current and is always less than the smallest individual resistance.
- When the total current is unknown and several resistors of equal value are connected in parallel, you can find the combined or joint resistance by dividing the resistance of one resistor by the number of resistors connected in parallel. For example, if two 10-ohm resistors are connected in parallel, the joint resistance offered by the combination is 5 ohms (10 / 2).
- To state this as a rule: The combined resistors of equal value connected in parallel are equal to one resistance value divided by the number of connected resistors.
- All equipment you use in electrical circuits does not have the same resistance. Therefore, when you connect different pieces of equipment in a parallel circuit, they do not draw the same current. Two unequal resistors connected in parallel are shown in Figure 5.

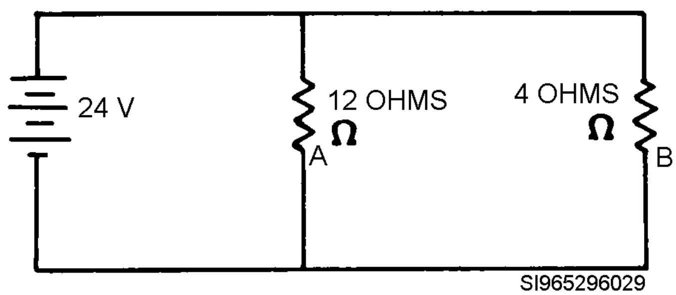


**Figure 5, Two Unequal Resistors Connected in Parallel**

- In this case, the current through the parallel connected resistor A is $I_A = E / R_A = 24 / 12 = 2$ amps.
- The current through resistor B is $I_B = E / R_B = 24 / 4 = 6$ amperes.
- The current is equal to the sum of the currents in the branches ($I_T = 6A + 2A = 8$ amperes).
- Ohm's law then gives the joint resistance offered by the current as $R_J = E / I_T = 24 / 8 = 3$ ohms.
- You could not use the rule for resistors of equal value in parallel circuits for this circuit because the individual resistors, A and B, are not equal in value.
- For such cases, another rule has been developed for the calculation of joint resistance: The joint resistance of two resistors in parallel is equal to their product divided by their sum. ($R_J$ = product / sum)
- If you substitute the values from the circuit in Figure 5, you have $R_J = (12 \times 4) / (12 + 4) = 48 / 16 = 3$ ohms.
- There is also another method of finding the joint resistance of several resistors in parallel. It is called the reciprocal method. As you have seen, you can use the product-over-sum

method with only two resistors at one time. If the circuit has five or six resistors in parallel, this could be a lengthy procedure.

- Instead you can use the reciprocal method to find the joint resistance of any number of resistors in one operation. The rule is the joint resistance of a parallel circuit is equal to the reciprocal of the reciprocals of the individual resistances.
- $R_J = 1/ [(1 / R_1) + (1 / R_2) + (1 / R_3)] = 1 / (1/2 + 1/3 + 1/6) = 1 / (.5 + .33 + .17) =1$ ohm.

**Application of Ohm's law to series-parallel circuits.**

- Series-parallel circuits consist of groups of parallel resistors in series with other resistors. Any leg of a parallel group can consist of two or more resistors in series.
- You can analyze series-parallel circuits by using the same rules we applied to series circuits and to parallel circuits. To make this application, reduce the series-parallel circuit to an equivalent, series or parallel circuit.
- Work only one part first, use the laws which apply to that part of the circuit.
- First, replace each group of parallel resistors with its equivalent single resistance.
- Then, treat the entire circuit as a series circuit.

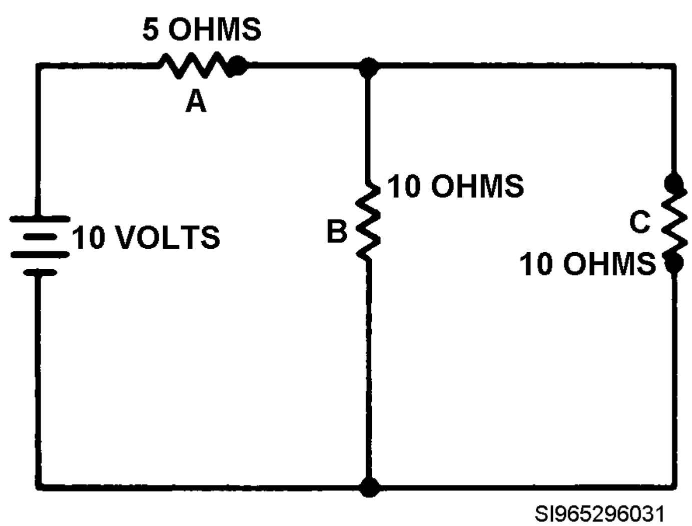


**Figure 6, Simple Series-Parallel Circuit**

- Figure 6 shows an example of a series-parallel circuit.
- The first step is to reduce the two parallel resistors B and C to an equivalent single resistance.
- Since B and C are equal, you can divide 10 by 2. This gives you 5 ohms as the joint resistance of the parallel branch.
- The circuit is now a series circuit of two 5-ohm resistors.
- Obtain the total resistance by adding the resistance A to the equivalent of B and C. This gives you 5 plus 5, or 10 ohms, as the resistance of the entire circuit.
- Knowing this, you can calculate the total current by applying Ohm's law:
- $I_T = E_T / R_T = 10 /10 = 1$ ampere
- This 1 ampere flows through resistor A, producing a voltage drop of 5 volts.
- Since the two parallel resistance's have the same value, the 1 ampere of current divides equally between the two. The IR drop across B equals ½ x 10, or 5 volts, and across C is 5 volts also.

- By following one complete path around the circuit, you can see that the sum of the voltage drops is equal to the applied voltage. Starting from the positive side of the battery, there is a 5-volt drop in resistor A, another 5-volt drop in resistor B, and thus back to the battery. Follow only one path at a time in tracing through a circuit.

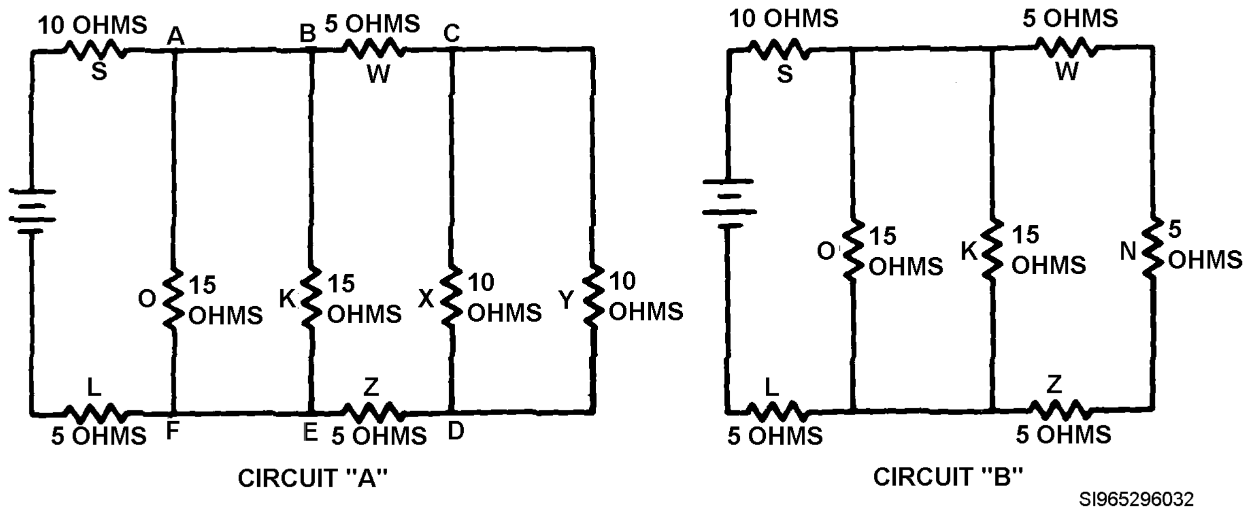


**Figure 7, Solving Series-Parallel Circuits Simplified**

- In Figure 7 there is a series-parallel circuit that involves more steps, as you will see.
- Combine resistor X and Y of circuit A and represent them with resistance N of circuit B.
- Circuit B is the equivalent circuit of circuit A in Figure 7.
- X and Y are equal and in parallel; therefore, their joint resistance is as follows:
- N = 10/2 = 5 ohms
- Combine resistors W, N, and Z (Circuit B of Figure 7) into a simple resistor M of circuit C in Figure 8.
- W, N, and Z are in series; therefore, the resistance of M equals 15 ohms (5+5+5=15).

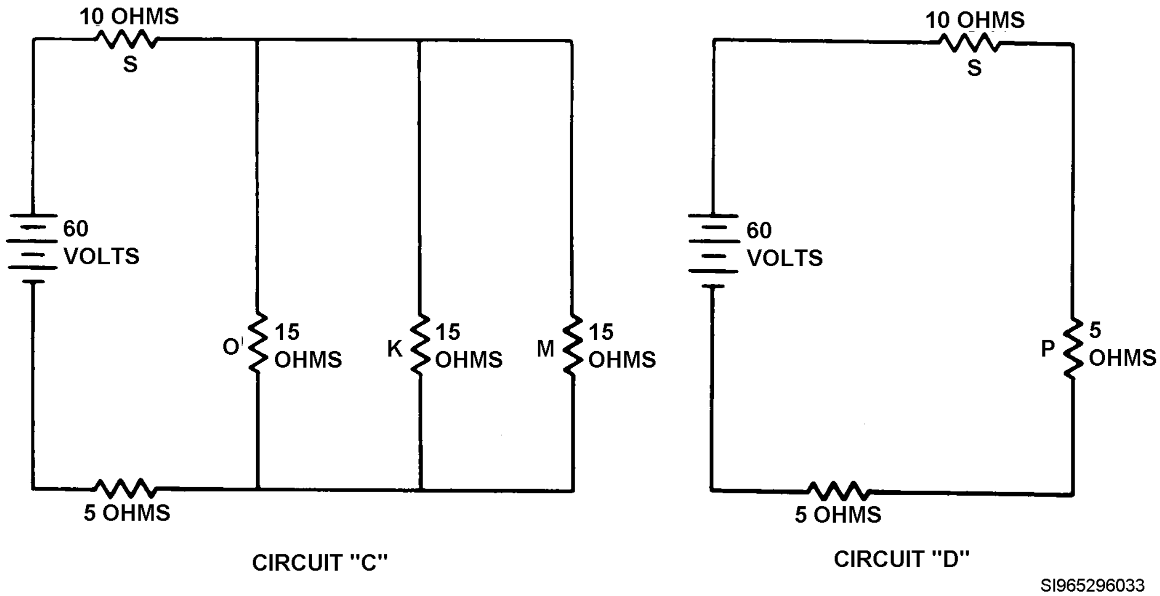


**Figure 8, Solving Series-Parallel Circuits by Simplified Equivalent Circuits**

- Combine resistors O, K, and M, of circuit C in Figure 8, into a simple resistance P of circuit D of Figure 8. Since resistors O, K, and M are equal and in parallel, treat them as follows:
- P = 15/3 = 5 ohms
- Combine resistors S, P, and L (circuit D, Figure 8), which are in series. The combined or joint resistance ($R_J$) of the whole circuit equals 20 ohms (10+5+5).
- Find the total current ($I_T$) of the circuit as follows:
- $I_T = E / R_T = 60/20 = 3$ amperes
- Find the voltage drop across S (circuit C, Figure 8) as follows: $E_S = I_T \times R_S = 3 \times 10 = 30$ volts
- Find the voltage drop across L (circuit D, Figure 8) as follows: $E_L = I_T \times R_L = 3 \times 5 = 15$ volts
- Find the voltage drop across equivalent resistance P (equivalent of O, K, M, circuit C) as follows: $E_P = E_T - E_S - E_L = 60 - 30 - 15 = 15$ volts
- The voltage drop across each parallel branch is equal. Find the current in resistor O as follows:
- $I_O = E_O / R_O = 15 / 15 = 1$ ampere
- At point A of circuit A, Figure 7, there are two paths for the current flow. In a parallel circuit, the total current equals the sum of the currents in the branches.
- Therefore, the current flowing from point A to point B equals $I_T - I_O$, or $3 - 1 = 2$ amperes.
- The voltage drop across parallel resistors is equal, so the voltage drop across K is 15 volts. The current is $I = E / R = 15 / 15 = 1$ ampere.
- Since a current of 2 amperes flows from point A to point B and 1 ampere of current flows through resistor K, the current through W must be 1 ampere (2 – 1).
- At C the current divides again. Since the resistances X and Y are the same, the current divides equally, with ½ ampere going through each resistor.
- Voltages across X and Y are the same. $E = I \times R = ½ \times 10 = 5$ volts.

- At C to D of circuit A (Figure 7) the two currents of ½ ampere join and 1 ampere flows through Z. Voltage drop across Z is 5 volts. ( $E = I \times R = 1 \times 5 = 5$)
- At point E, the currents through Z and K join and 2 amperes (1 + 1) flow through E to F.
- At point F, the current flowing through O joins the current flowing from point E to F and 3 amperes flow through L. Recall that this 3 amperes is equal to the total current.

**Determine power in a DC circuit.**

- To determine the power in a DC electrical circuit, use the power formula $P = E \times I$.
- For example, a circuit with an applied voltage of 120 volts and a current flow of 10 amperes consumes 120 volts x 10 amperes, or 1,200 watts.
- You can also find the power in a DC circuit if you know the resistance (R) by using the following formula: $P = E^2 / R$ or $P = I^2R$

> **NOTE:**
> Many of the ideas you absorbed in your study of DC circuits are applicable to AC circuits. The constant changing of the direction and the magnitude of alternating current cause those features that you found to be different. The rules and equations for DC circuits apply to AC circuits having resistive load elements alone. This includes load elements such as lamps, resistors, and heating elements. When the AC circuit contains reactive load elements, we must take them into consideration also because the current through a reactive component is not in phase with the applied voltage. We must take the effect of this out-of-phase condition when we calculate values in AC circuits.

***To perform the task, follow these tasks:***

**Step 1 Using ohms law compute for voltage.**

- In a circuit where total resistance and current are known use formula $E=IR$
- In a series circuit, first find voltage at each resistor using formula $E_1=IR_1$. Then find total voltage using formula $E_T=E_1+E_2+$ect.
- In a parallel circuit, first find total current using formula $I_T=I_1+I_2+$ect. Then find total resistance using formula $R_J=E/I_T$. Place these totals in formula $E=I_TR_J$.

**Step 2 Using ohms law compute for current**

- In a circuit where total resistance and voltage are known use formula $I=E/R$
- In a series circuit first find total resistance using formula $R_T=R_1+R_2+$ect. Then find total voltage using formula $E_T=E_1+E_2+$ect. Then find total current using formula $I=E_T/R_T$
- In a parallel circuit, first find current at each resistor using formula $I_A=E/R_A$. Then find total current using formula $I_T=I_1+I_2+$ect.

**Step 3 Using ohms law compute for resistance**

- In a circuit where total current and voltage are known use formula $R=E/I$
- In a series circuit find the totals of voltage and current using formulas $E_T=E_1+E_2+$ect and $I_T=I_1=I_2=$ect. Then find total resistance using formula $R_T = E_T/ I_T$.
- In a parallel circuit, find the totals of voltage and current using formulas $E_T=E_1= E_2=$ect and $I_T=I_1+I_2+$ect. Then find total resistance using formula $R_T = E_T/ I_T$.

**Step 4 Determine power in a circuit**

- To determine power in a simple DC electrical circuit, use the power formula $P = E \times I$.
- For example, a circuit with an applied voltage of 120 volts and a current flow of 10 amperes consumes 120 volts x 10 amperes, or 1,200 watts.
- You can also find the power in a DC circuit if you know the resistance (R) by using the following formula: $P = E^2 / R$ or $P = I^2R$

# Review Questions
## for
# Compute for Voltage, Current, Resistance, and Power

| Question | Answer |
|---|---|
| 1. In mathematical equations, what is the symbol for current? | a. “C”<br>b. “I”<br>c. “E”<br>d. “R” |
| 2. A direct current-series circuit has two or more paths for current to flow. | a. True<br>b. False |
| 3. In a direct current-series circuit the same current flows in each part of the circuit. | a. True<br>b. False |
| 4. A method of finding the joint resistance of several resistors in parallel is called the _______ method. | a. Parallel<br>b. Ohm’s<br>c. Sum<br>d. Reciprocal |
| 5. What formula is used to determine the power in a DC circuit? | a. P = I x R<br>b. P = I / E<br>c. P = E x I<br>d. P = E x R |

## COMPUTE FOR VOLTAGE, CURRENT, RESISTANCE, AND POWER

| **Performance Checklist** | | |
|---|---|---|
| **Step** | **Yes** | **No** |
| 1. Did the trainee properly apply Ohm's law to compute for voltage? | | |
| 2. Did the trainee properly apply the power formula to compute power? | | |
| 3. Did the trainee properly apply Ohm's law to compute for current? | | |
| 4. Did the trainee properly apply Ohm's law to compute for resistance? | | |

**FEEDBACK:** Trainer should provide both positive and/or negative feedback to the trainee immediately after the task is performed. This will ensure the issue is still fresh in the mind of both the trainee and trainer.

# ELECTRICAL FUNDAMENTALS

## MODULE 13 AFQTP UNIT 5

## MEASURE ELECTRICAL PROPERTIES IN CIRCUITS AND COMPONENTS (13.5.)

# MEASURE ELECTRICAL PROPERTIES IN CIRCUITS AND COMPONENTS

## *Task Training Guide*

| | |
|---|---|
| **STS Reference Number/Title:** | 3.5. – Electrical fundamentals, measure electrical properties in circuits and components |
| **Training References:** | • CDC 3E051A Vol.2 Electrical and Electronic Fundamentals |
| **Prerequisites:** | • Possess as a minimum a 3E031 AFSC. |
| **Equipment/Tools Required:** | • Voltmeter<br>• Ohmmeter<br>• Megohmmeter<br>• Ammeter |
| **Learning Objective:** | • Given meters, measure electrical properties in circuits and components |
| **Samples of Behavior:** | • Differentiate between meters and their functions.<br>• Use meters to measure electrical properties in circuits and components. |
| **Notes:** | |
| • Any safety violation is an automatic failure. | |

**Notice.** This AFQTP is *NOT* intended to replace the applicable technical references nor is it intended to replace hands-on training. It is to be used in conjunction with these for training purposes only.

## MEASURE ELECTRICAL PROPERTIES IN CIRCUITS AND COMPONENTS

**Background:** When working on electrical equipment, you often need to know things about the circuit that you cannot visually detect. Various meters are necessary in order to check for the proper voltage, current flow, and amount of resistance and to determine if the wiring is defective. You must remember that the purpose of a meter is to measure quantities. When a meter is connected to a circuit, it must not change the condition of the circuit.

***To complete the task, follow these steps:***

**SAFETY:**
**REMOVE ALL JEWELRY WHEN USING VOLT, OHM, MEGOHMETER, OR AMP METERS.**

**Step 1: Voltmeters.**
- Set the meter to the highest voltage scale when the voltage is unknown.
- Always observe polarity when measuring DC voltage.
- Disregard polarity when measuring AC voltage.
- Connect the meter in parallel with the circuit being measured.
- If the needle moves only a small amount, move the selector to a lower range to get a more accurate reading.

**Step 2: Ohmmeters.**
- Make sure the circuit or equipment is de-energized.
- Zero the meter by touching the leads together and turning the ohms zero knob until the pointer is at the zero mark.

NOTE:
Zero the meter each time you select a new range.

- Isolate the circuit to be tested.
- Make sure that your hands do not touch the uninsulated portion of the meter leads, your body resistance will distort the reading.
- If you are using an analog meter and do not get ¾ scale deflection on the needle when making your measurement, go to a more sensitive (lower) setting.

**Step 3: Megohmeters**
- Megohmeters are primarily used for insulation resistance testing, they read directly in millions of ohms.
- Megohmeters are used in the same way as ohmmeters, the difference is the voltage.
- They put out either 500 or 1000 volts at low amperage.

**Step 4: Ammeters.**

- Ammeters measure the amount of current flowing in an electrical circuit.
- Connect ammeters in series with the circuit.
- Always select the highest range first when the amperage is unknown.
- On analog meters, if the needle only moves a small amount, select a lower range.
- Observe polarity when measuring current flow in DC circuits.

**Step 5: Multimeters.**

- Multimeters handle all the functions of Amp, Volt, and Ohm meters in one convenient package.
- The operation of the multimeter is the same as for the individual meters, but you must select the function on the face of the meter.

**Step 6: Clamp-on Ammeter.**

- There are times when you need to measure amperage in a circuit without disconnecting the circuit. The easiest way to do this is with a clamp-on ammeter.
- Select the highest amperage scale on unknown circuits.
- Clamp the jaws around one conductor at a time.
- If you are using an analog meter and scale deflection is less than ¾ of the meter scale, change to a lower scale.

# Review Questions
for
# Measure Electrical Properties in Circuits and Components

| Question | Answer |
|---|---|
| 1. Set voltmeter to the lowest scale when the voltage is unknown. | a. True<br>b. False |
| 2. Voltmeters are connected to the circuit in _________. | a. Series.<br>b. Parallel.<br>c. Series-Parallel.<br>d. Any of the above. |
| 3. You need only observe polarity on ________. | a. AC circuits.<br>b. DC circuits.<br>c. Combination circuits.<br>d. All of the above. |
| 4. Ohmmeters can be used on energized equipment. | a. True<br>b. False |
| 5. Megohmeters use the same voltage as ohmmeters, they just read in millions of ohms. | a. True<br>b. False |
| 6. Megohmeters measure current flow in an electrical circuit. | a. True<br>b. False |
| 7. Connect ammeters in ______with the circuit. | a. Parallel<br>b. Series<br>c. Series / Parallel<br>d. Any of the above |
| 8. Multimeters handle all the functions of volt, amp, megohm, and ohm in one convenient package. | a. True<br>b. False |
| 9. If the meter deflection on a clamp-on ammeter is less than ¾ scale deflection, switch to a _______range. | a. Newer<br>b. Higher<br>c. Lower<br>d. None of the above |
| 10. Ammeters can measure ______conductor at a time. | a. One<br>b. Two<br>c. Three<br>d. Four |

## MEASURE ELECTRICAL PROPERTIES IN CIRCUITS AND COMPONENTS

| Performance Checklist | | |
|---|---|---|
| **Step** | **Yes** | **No** |
| 1. Did trainee remove all jewelry? | | |
| 2. Did trainee set meters to highest scale first? | | |
| 3. Did trainee observe polarity in measuring DC circuits? | | |
| 4. Did trainee zero the ohmmeter before use? | | |
| 5. Did trainee use the proper setting on the multimeter? | | |
| 6. Did trainee measure only on conductor at a time? | | |

**FEEDBACK:** Trainer should provide both positive and/or negative feedback to the trainee immediately after the task is performed. This will ensure the issue is still fresh in the mind of both the trainee and trainer.

# Air Force Civil Engineer

## QUALIFICATION TRAINING PACKAGE (QTP)

## REVIEW ANSWER KEY

**For**

**ELECTRICAL SYSTEMS**

**(3E0X1)**

**MODULE 13**

**ELECTRICAL FUNDAMENTALS**

**Notice.** This AFQTP is *NOT* intended to replace the applicable technical references nor is it intended to replace hands-on training. It is to be used in conjunction with these for training purposes only.

## IDENTIFY ELECTRICAL TERMS AND SYMBOLS

## (3E0X1-13.1.)

| Question | Answer |
|---|---|
| 1. What is the unit of measure for current flow? | c. Ampere |
| 2. The symbol for quantity of amperes used on drawings is “I.” | b. False |
| 3. What is the definition of voltage? | b. The force that moves electrons in an electrical circuit. |
| 4. The unit of measurement for inductance is the farad. | b. False |
| 5. Power is the product of voltage and _____. | c. Current. |
| 6. The frequency of a system we formerly expressed in cycles per minute, but now express as hertz. | b. False |

## CONSTRUCT BASIC ELECTRIC CIRCUITS

## (3E0X1-13.3)

| Question | Answer |
|---|---|
| 1. A simple circuit is made up of a _________. | d. All of the above |
| 2. An electric circuit is a completed conducting pathway. | a. True |
| 3. What simple circuit is defined as one having more than one current path connected to a common voltage source? | b. Parallel |
| 4. How many units of resistance are required to form a series-parallel (complex) circuit? | b. Three |

## COMPUTE FOR VOLTAGE, CURRENT, RESISTANCE, AND POWER

## (3E0X1-13.4.)

| Question | Answer |
|---|---|
| 1. In mathematical equations, what is the symbol for current? | b. "I" |
| 2. A direct current-series circuit has two or more paths for current to flow. | b. False |
| 3. In a direct current-series circuit the same current flows in each part of the circuit. | a. True |
| 4. A method of finding the joint resistance of several resistors in parallel is called the _______ method. | d. Reciprocal |
| 5. What formula is used to determine the power in a simple DC circuit? | c. P = E x I |

## MEASURE ELECTRICAL PROPERTIES IN CIRCUITS AND COMPONENTS

## (3E0X1-13.5.)

| Question | Answer |
|---|---|
| 1. Set voltmeter to the lowest scale when the voltage is unknown. | a. True |
| 2. Voltmeters are connected to the circuit in _______. | b. Parallel. |
| 3. You need only observe polarity on ________. | b. DC circuits. |
| 4. Ohmmeters can be used on energized equipment. | b. False |
| 5. Megohmeters use the same voltage as ohmmeters, they just read in millions of ohms. | b. False |
| 6. Megohmeters measure current flow in an electrical circuit. | b. False |
| 7. Connect ammeters in ______with the circuit. | b. Series |
| 8. Multimeters handle all the functions of volt, amp, megohm, and ohm in one convenient package. | b. False |
| 9. If the meter deflection on a clamp-on ammeter is less than ¾ scale deflection, switch to a _______range. | c. Lower |
| 10. Ammeters can measure ______conductor at a time. | a. One |